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Modeling of a Monocular, Full-Color, Laser-Scanning, Helmet-Mounted Display for Aviator Situational Awareness

By Thomas H. Harding^{1,2}, Maria E. Raatz^{1,2},
John S. Martin^{1,2}, Clarence E. Rash¹

¹U.S. Army Aeromedical Research Laboratory

²UES, Inc.



United States Army Aeromedical Research Laboratory

Visual Health and Performance Division

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14. ABSTRACT <p>The modeling data and analysis presented in this paper was accomplished in 2003 by the authors. This manuscript represents early modeling efforts that assessed an operational question posed by the Project Manager (PM) for Aircrew Integrated Systems (the precursor to PEO Soldier's PM for Air Warrior). The question related to the mounting of a see-through, helmet-mounted display (HMD) to the ANVIS mount of an HGU-56P helmet. By attaching the HMD to the ANVIS mount, the HMD would be placed in front of the helmet's visor assembly. It was anticipated that for daylight missions, most aviators would deploy the tinted visor, thus reducing the ambient luminance reaching the eye. Mounting the HMD in front of the visor would increase the HMD luminance requirements as the neutral-density, tinted visor would attenuate the light coming from the HMD as well as the ambient scene by the same amount. What makes the present paper unique at the time was the idea of modeling HMDs by producing computer imagery for an observer to evaluate the quality of symbology.</p>											
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Foreword

The modeling data and analysis presented in this paper was accomplished in 2003 by the authors. In 2003, the first three authors were employees of UES, Inc., of Dayton, OH, under contract to the U.S. Army Aeromedical Research Laboratory. This manuscript represents early modeling efforts that assessed an operational question posed by the Project Manager (PM) for Aircrew Integrated Systems (the precursor to PEO Soldier's PM for Air Warrior). The question related to the mounting of a see-through, helmet-mounted display (HMD) to the ANVIS mount of an HGU-56P helmet. By attaching the HMD to the ANVIS mount, the HMD would be placed in front of the helmet's visor assembly. It was anticipated that for daylight missions, most aviators would deploy the tinted visor, thus reducing the ambient luminance reaching the eye. Mounting the HMD in front of the visor would increase the HMD luminance requirements as the neutral-density, tinted visor would attenuate the light coming from the HMD as well as the ambient scene by the same amount. Apache aviators routinely used the tinted visor during daylight operations; however, the Apache helmet display unit (i.e., the Apache HDU) was mounted behind the visor. The authors presented a paper, which also appeared as a publication in the SPIE Proceedings (Harding et al., 2006), at the SPIE HMD conference in 2006 addressing this question. This paper is unique because it was our first attempt at modeling an HMD by evaluating symbology and map imagery superimposed over real-world ambient scenes and artificial clutter. It is the idea of modeling HMDs to produce imagery that will in turn be evaluated by an observer that makes this paper unique and it laid the groundwork for future HMD modeling efforts by the authors.

No attempt by the authors was made to bring this manuscript up-to-date with current thinking and/or knowledge gained from a decade or more of modeling experience with see-through display optical systems.

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Introduction

This study began as a result of a program initiative by the Product Manager for Air Crew Integrated Systems to develop a full-color, monocular helmet-mounted display (HMD) to enhance operational situational awareness in the UH-60 Blackhawk helicopter. The future HMD will be loosely based upon the Virtual Cockpit Optimization Program (VCOP) HMD designed and produced by Microvision, Inc., Bothel, WA. The monocular HMD is being developed for daytime use and is intended to utilize the ANVIS mount on the HGU-56P helmet. A question arising from an early planning meeting was where to place the HMD in relationship to the HGU-56P visor. Mounting the HMD combiner lens inside the visor will require major modifications to the helmet and visor. Mounting the HMD combiner lens outside of the visor position complicates several issues (e.g., center of mass, image contrast, etc.). Using a previously developed simulation model (Harding et al., 2002), expected HMD performance characteristics were used to analyze the issues associated with the HMD and its position relative to the visor.

Modeled Parameters

Figure 1 depicts the tri-color spectra used for modeling the HMD. The 4-nanometer (4-nm) bandwidth lasers peak at 473 nm (blue), 532 nm (green), and 658 nm (red). As the model has a 2-nm resolution (even numbers only), the 473 nm laser was set to 474 nm. Using these emission spectra, we modeled a see-through transmission of the HMD's optics with a highly selective, triple-notch spectrum that is typical of rugate coatings. The see-through transmission spectra can be seen in Figure 2. We used a flat-transmission spectrum of 90% interrupted by notches centered at the peaks of the emission spectra. The notches had a bandwidth of 8 nm. At the center of the notches, the transmission was set to 20%.

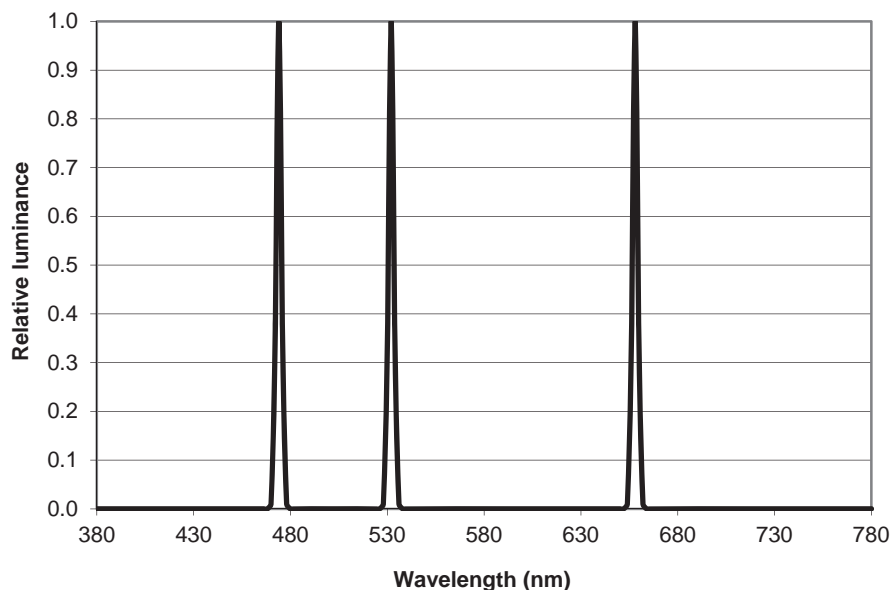


Figure 1. HMD Emission Spectra

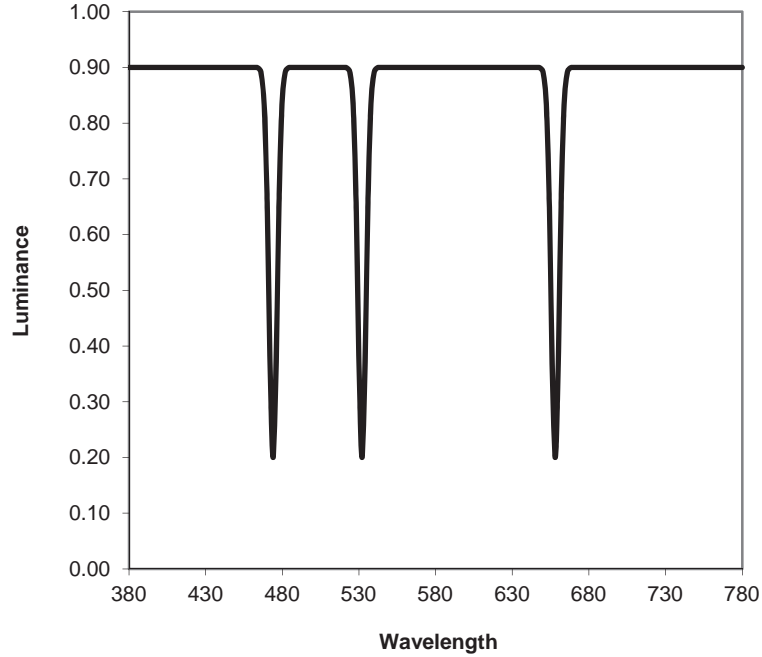


Figure 2. The modeled see-through transmission spectra of the HMD.

For purposes of our simulations, the HMD has a peak luminance of 1000 foot-lamberts (fL) with a contrast ratio of 33. This contrast ratio was derived from an evaluation of the VCOP HMD (Harding, et al., 2003). We used the 1000 fL value for symbology and situational maps regardless of the color. For calculating see-through grayshades, contrast ratios, and Michaelson contrast, we simulated skylight using a color temperature of 25,000 K by using the CIE S0, S1, and S2 variables. Separate S0, S1, and S2 values must be calculated for each wavelength. The color temperature chosen provides a predominantly blue sky with limited contribution from the red portion of the spectrum.

As the proposed HMD is to be used on the UH-60 aircraft, we used the windscreen transmission spectrum from that aircraft. For modeling visors, we used the Gentex clear, tinted, laser (2-notch) and 3-notch visors. Note: As some of these spectra are sensitive, only the modeling results using these visors are presented and not their spectra.

The average background luminance L_B is represented by

$$L_B = L_{DB} + L_{AE}$$

where L_{DB} is display background luminance at the eye, and L_{AE} is the ambient luminance at the eye. L_B is used in the following formulas for contrast ratio (CR), grayshades (GS), and Michaelson contrast (C_M).

$$CR = (L_{DF} + L_B) / L_B$$

$$GS = 1 + (\log(CR) / \log(2^{0.5}))$$

$$C_M = L_{DF} / (L_{DF} + L_B)$$

where L_{DF} is display foreground and is set to 1000 fL in all calculations.

Results

To handle almost any daylight luminance, simulations were performed at various skylight luminances from 500 to 10,000 fL for every combination of visor and HMD position. Figures 3 and 4 show the results of these simulations for Michaelson contrast. Figure 3 shows contrast for the HMD mounted outside the visor. Note that the “no visor” and “tinted visor” contrast values are nearly identical with the HMD positioned outside the visor. This is because the tinted visor attenuates the background and the HMD emission spectrum by about the same amount. For these calculations, the emission spectrum was white and therefore all lasers were equally represented. As expected, the Gentex Laser (2-notch) visor and, especially, the Gentex 3-notch visor attenuate the contrast substantially. At 2,000 fL luminance and above, contrast is reduced to below 50% for all conditions.

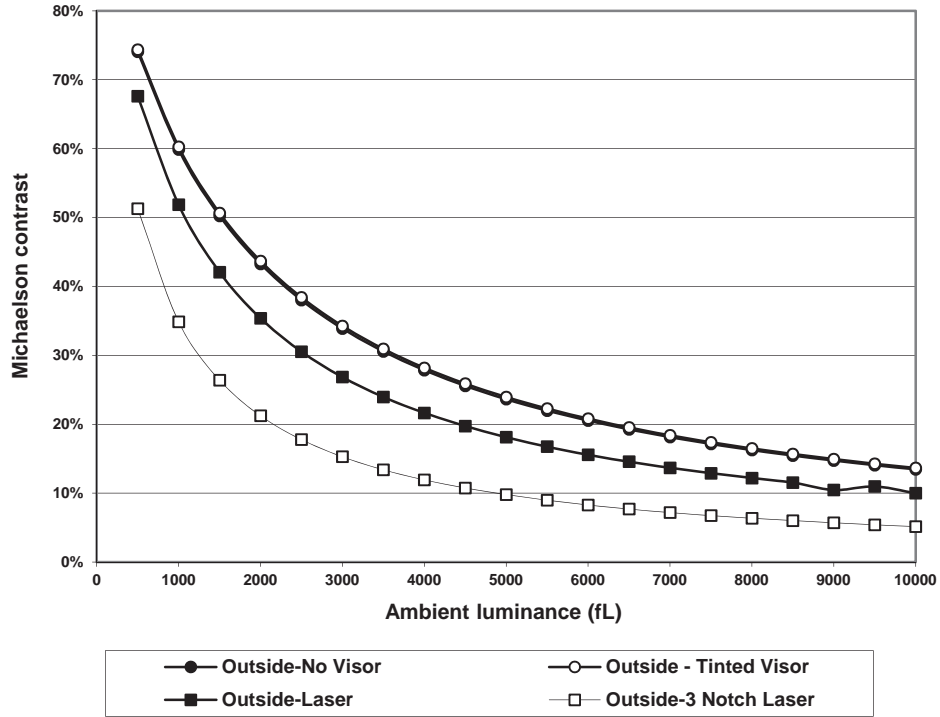


Figure 3. Michaelson contrast as a function of ambient luminance for the HMD mounted outside the visors.

In Figure 4, the same calculations are performed with the HMD mounted inside the visor. As expected, contrast is increased substantially for all visor conditions. Of course the no-visor condition is the same curve as seen in Figure 3. By way of comparison, the no-visor condition represents the highest contrast observed in Figure 3 and the lowest contrast observed in Figure 4. With the neutral density offered by the Gentex tinted visor, 50% contrast is achieved out to 10,000 fL.

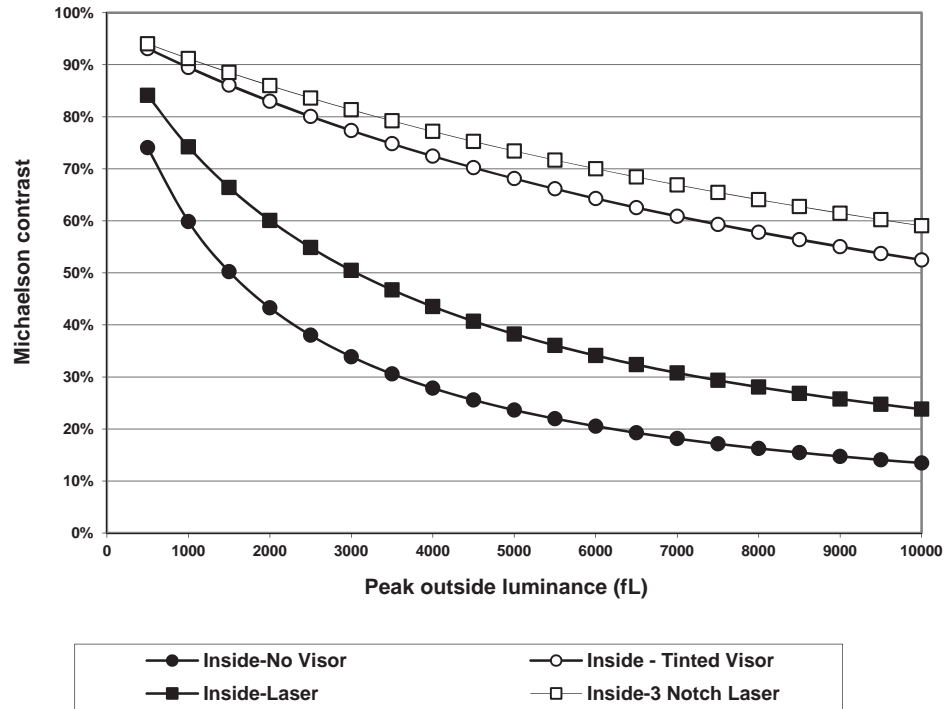


Figure 4. Michaelson contrast as a function of ambient luminance for the HMD mounted inside the visors.

As a summary, Appendix 1 has figures depicting all of the conditions in Figures 3 and 4 for contrast ratios and grayshades. Essentially, the same conclusions can be drawn regardless of the contrast measurement.

Visualization

To visualize symbology under varying conditions and luminance levels, simulations were run with the visualization model developed by UES, Inc. The purpose of the model is to simulate real world viewing of images as though the observer was looking through the hardware (i.e., HMD, visor, windscreen, etc.). Of course, no model can accurately simulate real world conditions. This is an extremely complex issue and is beyond the realm of this paper. A major problem is that the eye can see contrast over a several-log-unit range of ambient luminance. Most computers can only address a maximum of 256 gray levels per color, and actual displayed gray levels (on the monitor) are considerably less than 256. To handle this limitation, images are generally scaled so that the peak luminance is set to 255. Another problem lies in using transmissivity spectra to filter RGB imagery. The model currently translates the transmissivity curves to the 1964 CIE Colorimetric system and calculates the x-y chromaticity coordinates. Likewise, the x-y coordinates are calculated for the monitor's RGB spectra. Given these coordinates, the model solves for the RGB coefficients representing the hardware transmissivity curve. Given the coordinates, the model then solves for the RGB values. The present model assumes that the monitor's gamma is linear.

Figure 5 shows background images used to simulate outside-the-cockpit imagery. Two of the images are photographs while the third is a synthetic image of high contrast clutter. The

images shown in Figure 5 have sufficient luminance and spatial inhomogeneity to offer challenges to readability of symbology. The top image is a rather skewed image of clouds (histogram skewed to the right) while the second image is of ground clutter and is skewed more to darker regions. The third image has been equalized and its gray levels (i.e., luminance) are equally distributed. The model uses peak values in the image for scaling purposes when making composite images (image of background with overlaid symbology).

Figure 6 shows the symbology and map images used to simulate HMD imagery. The imagery is essentially multiplied by the emission RGB values to simulate the tri-color system. In the majority of simulations, the images are not altered since the emission is set to white (i.e., all lasers on).

Simulation results were obtained for “peak” luminances from 1,000 to 9,000 fL. Table 1 gives the “average” simulated luminance within each image for the five different luminance levels. In Appendix 2, Figures A2-1 through A2-5 show composite images, of symbology (Figure 6) plus backgrounds (Figure 5), for each peak luminance level shown in Table 1, for the HMD mounted inside and outside the visor. The visor used in the simulation was the Gentex tinted visor. Figures A2-6 through A2-10 in Appendix 2 show the same simulations but now using the situational map of Figure 6 rather than the symbology.

Table 1. Average Simulated Luminance (fL) for Each of the Five Peak Luminance Conditions.

Peak Luminance (fL)	Cloud Image	Ground Image	Synthetic Clutter
1000	648	413	713
3000	1944	1239	2139
5000	3240	2065	3565
7000	4536	2891	4991
9000	5832	3717	6417

In general, the greater the background clutter the lower the visibility of the symbology or situational map. As expected, from Figures 3 and 4, symbology and maps were much easier to see for the “inside-the-visor” condition. Trying to summarize the images is difficult given the complexity of the problem. However, it should be possible to perceptually quantify the images by comparing the readability of the symbology or maps. Clearly, both the symbology and maps are easier to discriminate against the clouds and hardest to discriminate against the synthetic clutter.

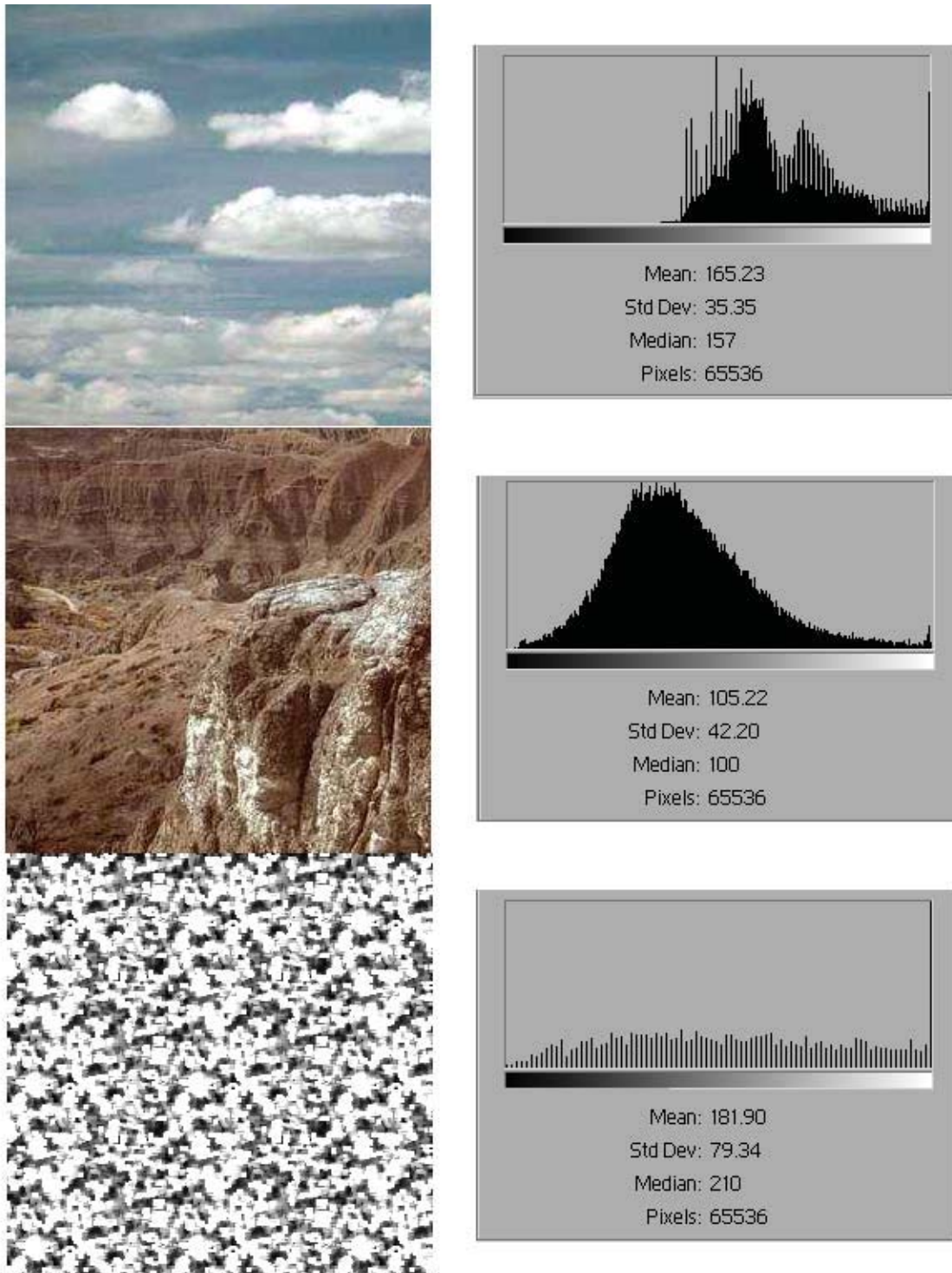


Figure 5. Background imagery used in simulation study along with statistical profiles.

In Table 2, we attempt to define a usable limit of the HMD symbology for each of the background images and HMD positions. We are using the notation of five pluses (+++++) for good quality, easily read imagery, and a single plus (+) for imagery that cannot be read. In Table 3, we use the same system for evaluating HMD map imagery. Although the scaling is subjective,

the results offer insight into the deterioration of the HMD imagery with increases in ambient luminance.

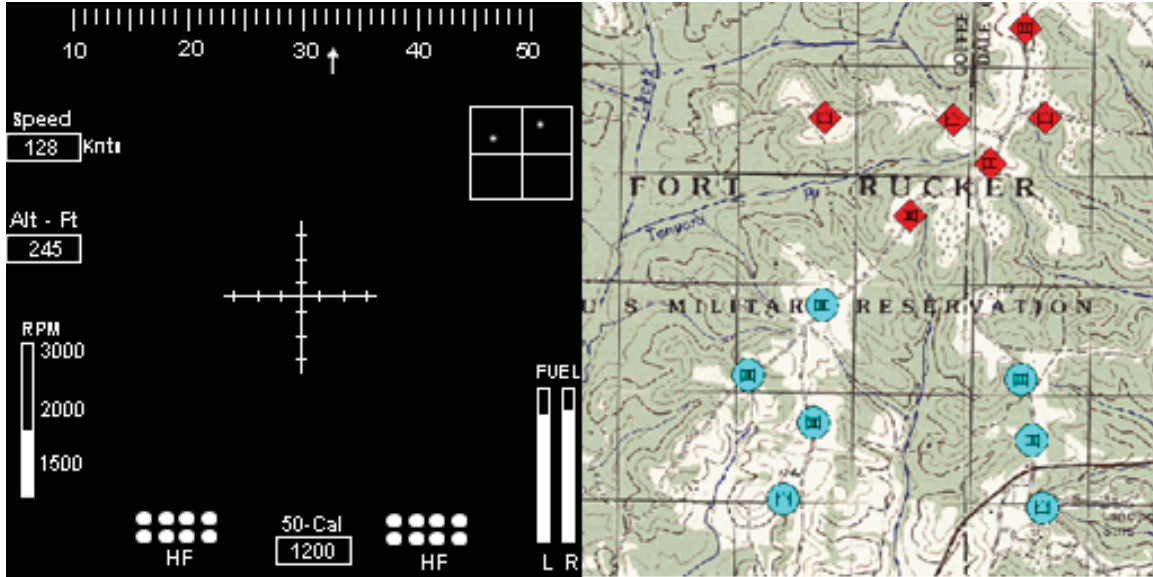


Figure 6. Symbology (left) and situational map (right) used to simulate HMD imagery.

Table 2. Grading of HMD Symbology as a Function of Peak Luminance.

Peak Luminance	Cloud Image		Ground Image		Synthetic Clutter	
	Inside	Outside	Inside	Outside	Inside	Outside
1000	+++++	++++	++++	+++	+++	++
3000	+++++	+++	+++	++	++	+
5000	+++++	+++	+++	++	++	+
7000	++++	++	++	+	++	+
9000	++++	++	++	+	+	+

Table 3. Grading of HMD Map Imagery as a Function of Peak Luminance.

Peak Luminance	Cloud Image		Ground Image		Synthetic Clutter	
	Inside	Outside	Inside	Outside	Inside	Outside
1000	+++++	+++	++++	+++	+++	+
3000	+++++	++	+++	+	++	+
5000	+++	++	+++	+	++	+
7000	+++	+	++	+	+	+
9000	++	+	++	+	+	+

By relating the subjective data in Tables 2 and 3 to the curves shown in Figures 3 and 4, we can roughly relate Michaelson contrast to some functional description (see Discussion for further detail). If we use a score of “+++” as usable and “+” or “++” as unusable, we can determine the contrast required to produce usable imagery for the three background images. Table 4 summarizes such a comparison.

Table 4. Subjective Requirements of Michaelson Contrast for the Three Backgrounds.

	Cloud Image		Ground Image		Synthetic Clutter	
	Inside	Outside	Inside	Outside	Inside	Outside
Symbology	undetermined, < 53%	24%	68%	60%	93%	undetermined, >74%
Mapping	51%	60%	61%	60%	93%	undetermined, >74%

While more data is required with much finer resolution to do justice to this kind of comparison, a quick glance at Table 4 reveals a pattern. Less contrast is required for the cloud and ground imagery than for the synthetic imagery, and only in the cloud condition did the symbology require less contrast than did the map. There should be little difference between the contrast requirement for inside or outside imagery, and that seems to hold within the data. Three conditions fell outside the range of measured data and for these conditions the nearest measured contrast was presented. The three background images used can be characterized by their inhomogeneity. From the contrast requirements, the background images can be ranked as to their ability to interrupt an observer's recognition of the foreground image. For these three images, the synthetic clutter posed the greatest difficulty followed by the ground image and then the cloud image. It appears that, the greater the background clutter, the higher the contrast requirements.

For homogeneous backgrounds, however, very little contrast is required. Figure 7 shows the symbology against a 10,000 fL uniform see-through background. The image on the left was produced with the HMD mounted outside the visor. The image on the right was calculated using a Gentex tinted visor and the HMD mounted inside the visor. Michaelson contrast for the two images should be about 13% for the image on the left and 52% for the image on right.

Color Contrast

Thus far, all of the modeling has been performed with white light. Changing the color of the symbology can make it more or less visible against most any real world scene. As an example of the difference color can make, Figure 8 depicts four simulations each with different colored symbology. The white symbology in the image was judged a “++” in Figure A2-4 for the same conditions. As a comparison, the green and red symbology, would likely be judged a “+++” or “++++”, while the blue symbology would likely be graded a “+”. Thus by only changing the color of the symbology, large differences in perceptual image quality are observed.

It is beyond the realm of this study to evaluate color contrast, but color contrast can make a difference.

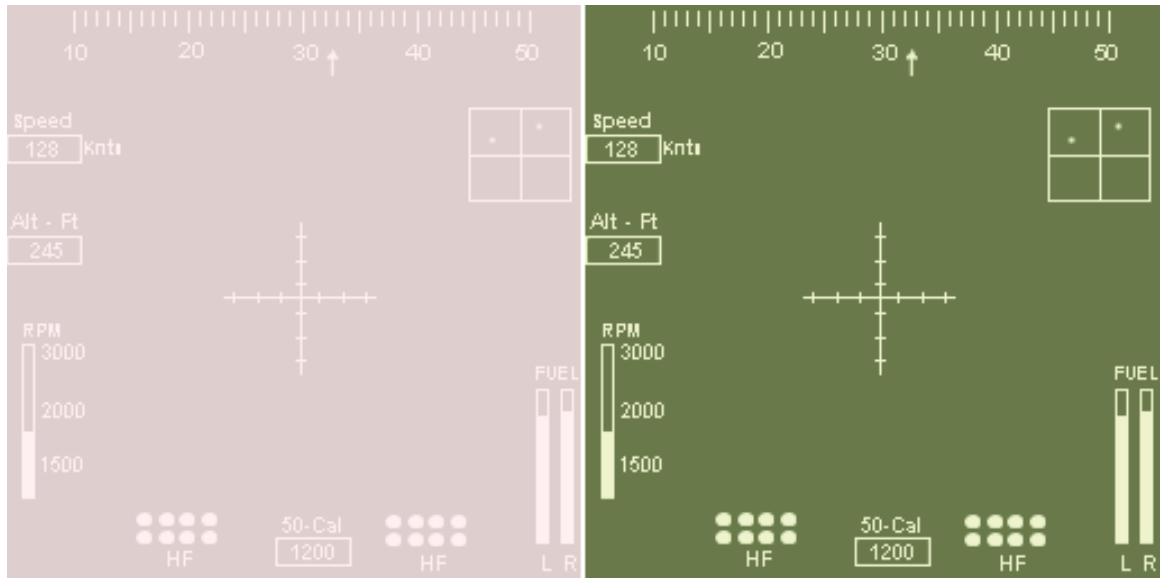


Figure 7. Composite images of symbology against a flat background. The image on left was obtained with HMD mounted outside the tinted visor and the image on the right was obtained with HMD inside the tinted visor. Ambient luminance was set to 10,000fL.

Using the HMD at Night

It is our understanding that current (as of 2003) aviation doctrine requires both pilots to wear night vision goggles (NVGs) at night. To use the proposed HMD at night would likely require a waiver. Of course, the HMD would have to be ANVIS compatible, meaning that the red laser would have to be turned off. Figure 9 shows the HMD RGB spectra along with the sensitivity of the Class A ANVIS. The red laser is near the peak sensitivity of the ANVIS goggle. Therefore at night, the red laser would have to be turned off.

Discussion

Regardless of the course of action taken, trade-offs must be made. Here, we examine the obvious trade-offs and a few subtle ones as well.

For daytime use, mounting the HMD inside the visor maximizes contrast and readability of HMD imagery. In the case of the tinted visor, it increases the range of ambient luminances that the HMD can effectively operate by about a factor of six. The Gentex tinted visor reduces the ambient luminance, thereby maximizing all measures of contrast. However, mounting the HMD inside the visor requires structural modifications to visors and perhaps even the helmet.

Of course, filters can be placed in front of the HMD, thus reducing or even eliminating the ambient luminance through the HMD. However, given the rather small field-of-view (FOV) of the HMD, a veiling glare condition would surround the HMD's FOV. Veiling glare reduces contrast and also makes visual search difficult. Increasing the area coverage of the filter placed in front of the HMD would make the HMD rather unwieldy and certainly add to center of mass problems already inherent with the HMD mounted so far forward.

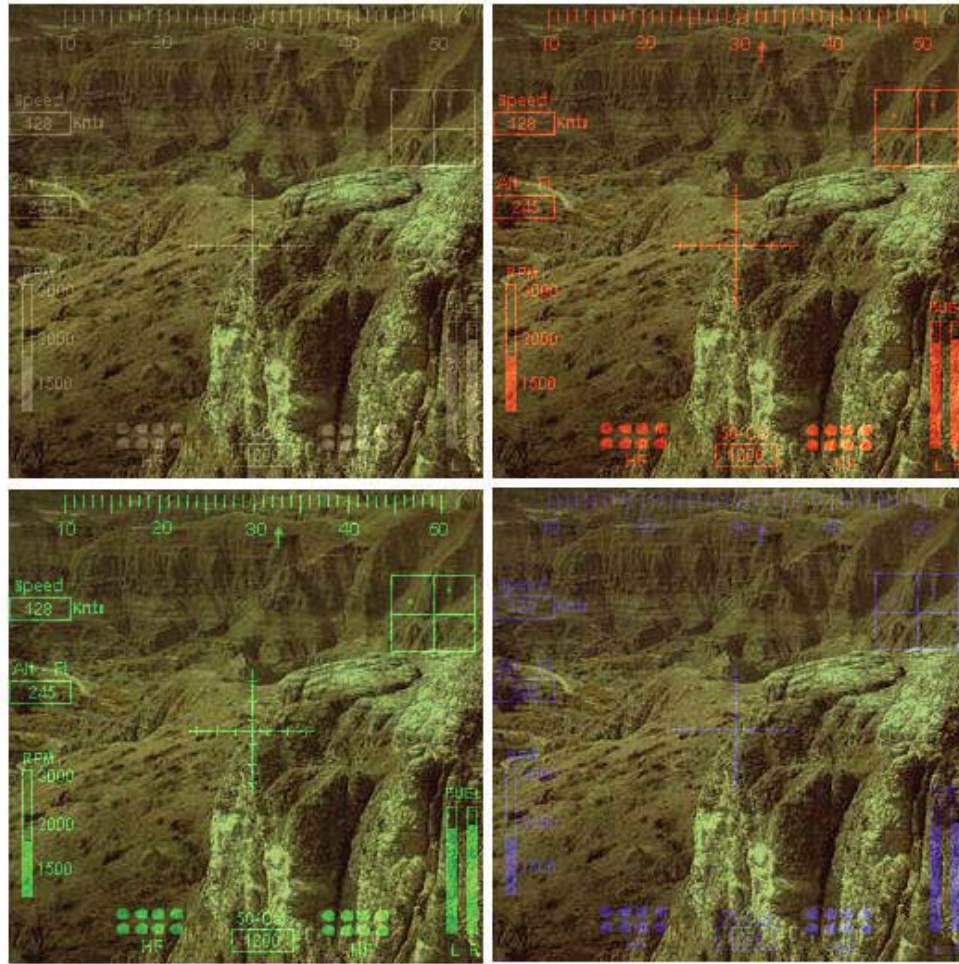


Figure 8. Four simulations of colored symbology. The ambient luminance is set at 7,000 fL with the HMD positioned in front of a Gentex tinted visor.

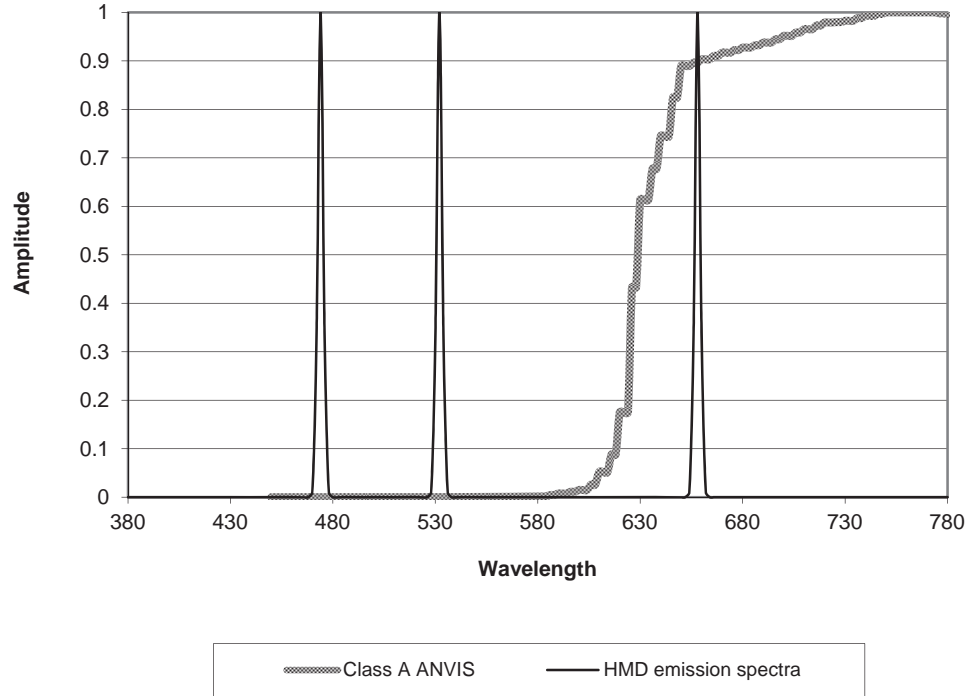


Figure 9. HMD emission spectra and the Class A ANVIS sensitivity curve.

Ambient Conditions

To determine the ambient luminance range over which the HMD can produce effective imagery is difficult. Evaluating Table 4 provides some insight into the matter. First, background imagery is an important consideration. Simply compare the imagery in Figure 7 with any of the images in Appendix 2. For our purposes, inhomogeneity of the background can be considered noise. Noise simply adds to the contrast signal, thus masking the contrast signal. The greater the noise, the greater the masking potential.

In Table 4, Michaelson contrast figures were derived for the data presented in Tables 2 and 3. These figures should be considered minimal for each condition since our image analysis was based upon peak luminance within each image and the contrast measures were based on ambient or average luminance. Table 1 shows the average luminance for each of the background images as a function of peak luminance. The averages are of course considerably less than the peaks. Therefore, for these simulations the contrast shown in Table 4 should be considered a minimal contrast requirement.

For the sake of closure, we can speculate as to the limitations of the modeled HMD imagery. We feel justified to use a 20% minimal contrast figure for homogeneous backgrounds (see Figure 7) and a 50% to 90% contrast figure for inhomogeneous backgrounds (from Table 4). Using these figures as basis, Table 5 summarizes the ambient luminance limitations for homogeneous and inhomogeneous backgrounds using the Gentex tinted visor.

Table 5. Ambient Luminance (fL) Limitations of HMD Imagery with Gentex Tinted Visor.

HMD Position	No Background Clutter	Low Background Clutter	High Background Clutter
Outside-the-Visor	6,000	1,500	<500
Inside-the-Visor	>10,000	10,000	1,000

Thus against a uniform sky, the HMD mounted in front of the visor could be used up to ambient conditions of 6,000 fL. As soon as the background becomes inhomogeneous, minimal contrast cannot be achieved beyond 1,500 fL. Of course, with the system mounted inside the visor, the aviator should have little difficulty reading the HMD imagery over most daylight conditions given the following warning:

As we are not differentiating here between symbology and maps, a word of caution is required. A symbology set does not change and the pilot has knowledge about the set and spatial location of all indicators. In our symbology example (Figure 6), the aviator does not have to read the word fuel to decipher the actual fuel level from the shading indication. Likewise, engine speed and missile inventory can be easily deciphered because of the shading. On the other hand, speed, and heading require the pilot to read the actual numbers. For situational maps, because they are fluid by definition, there exists positional and content uncertainty. To deal with this uncertainty, greater image quality is required for maps, and a key component of image quality is contrast. Thus, our grouping of maps and symbology is rather tenuous.

Summary

- A. The proposed system is designed for daytime use.
 - 1. Situation maps are harder to comprehend against a see-through background.
 - a. Contrast reduced.
 - b. Distractive imagery.
 - c. Maps are more difficult to understand than symbology.
 - 2. The system is not compatible with a night mission.
 - a. The full-color system is incompatible with ANVIS (the red laser would have to be turned off).
 - b. Current U.S. Army aviation doctrine requires both pilots to use NVGs.
- B. For the HMD mounted outside the visor:
 - 1. Increases size of HMD combiner optics and produces undesirable center-of-mass problems.
 - a. Counterweight likely required.
 - b. Increases crash risk factors for neck and head injuries.
 - 2. Limits the daytime usefulness of the HMD imagery.
 - a. With the Gentex tinted visor
 - i. 6,000 fL ambient luminance limitation against uniform backgrounds.
 - ii. 1,500 fL ambient luminance limitation against low cluttered backgrounds.
 - iii. Less than 500 fL limitation against high clutter backgrounds.
 - b. With the Gentex laser 2-notch visor
 - i. 4,500 fL ambient luminance limitation against uniform backgrounds.

- ii. 1,000 fL ambient luminance limitation against low cluttered backgrounds.
 - iii. Less than 500 fL limitation against high clutter backgrounds.
 - c. With the Gentex 3-notch visor
 - i. 2,000 fL ambient luminance limitation against uniform backgrounds.
 - ii. 500 fL ambient luminance limitation against low cluttered backgrounds.
 - iii. Less than 500 fL limitation against high clutter backgrounds.
- C. For the HMD mounted inside the visor:
 1. Requires modification to the current HGU-56P visors and/or HGU-56P helmet.
 2. Reduces size of HMD combiner optics and produces less impact upon the helmet center-of-weight.
 3. Increases the daytime usefulness of the HMD imagery.
 - a. With the Gentex tinted visor
 - iv. >10,000 fL ambient luminance limitation against uniform backgrounds.
 - v. 10,000 fL ambient luminance limitation against low cluttered backgrounds.
 - vi. 1,000 fL limitation against high clutter backgrounds.
 - b. With the Gentex laser 2-notch visor
 - vii. >10,000 fL ambient luminance limitation against uniform backgrounds.
 - viii. 3,000 fL ambient luminance limitation against low cluttered backgrounds.
 - ix. Less than 500 fL limitation against high clutter backgrounds.
 - c. With the Gentex 3-notch visor
 - x. >10,000 fL ambient luminance limitation against uniform backgrounds.
 - xi. >10,000 fL ambient luminance limitation against low cluttered backgrounds.
 - xii. 1000 fL limitation against high clutter backgrounds.
 4. Would likely increase fielding acceptance.

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References

- Harding, T. H., Klymenko, V., Martin, J. S., and Rash, C. E. (2002). An operational helmet-mounted display model: prediction of visible grayshades and see-through spectral data. *Proceedings of the SPIE*, 4711, 290-298.
- Harding, T. H., Martin, J. S., Beasley, H. H., and Rash, C. E. (2003). *Evaluation of the Microvision helmet-mounted display technology for synthetic vision application engineering prototype for the virtual cockpit optimization program*. (Report No. 2004-02). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory.
- Harding, T. H., Martin, J. S., and Rash, C. E. (2006). Performance effects of mounting a helmet-mounted display on the ANVIS mount of the HGU-56P helmet. *Helmet- and Head-Mounted Displays: Technologies and Applications*; edited by Randall W. Brown, Perter L. Marasco, Clarence E. Rash, and Colin Reese. *Proceedings of the SPIE*, 622409, 1-7.

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Appendix A. Grayshades

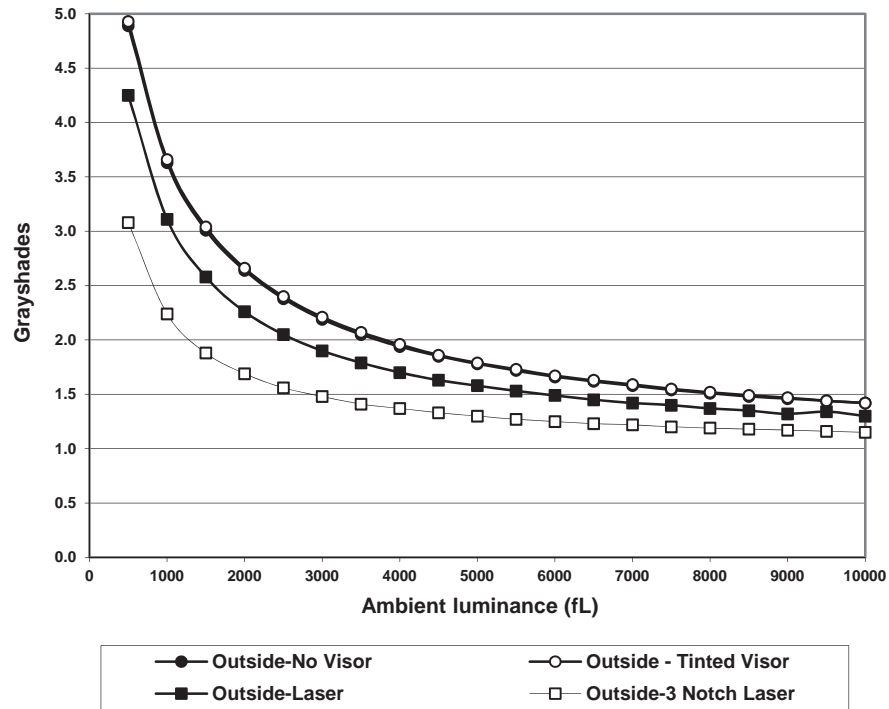


Figure A-1. Grayshades as a function of ambient luminance for the HMD mounted outside the visors.

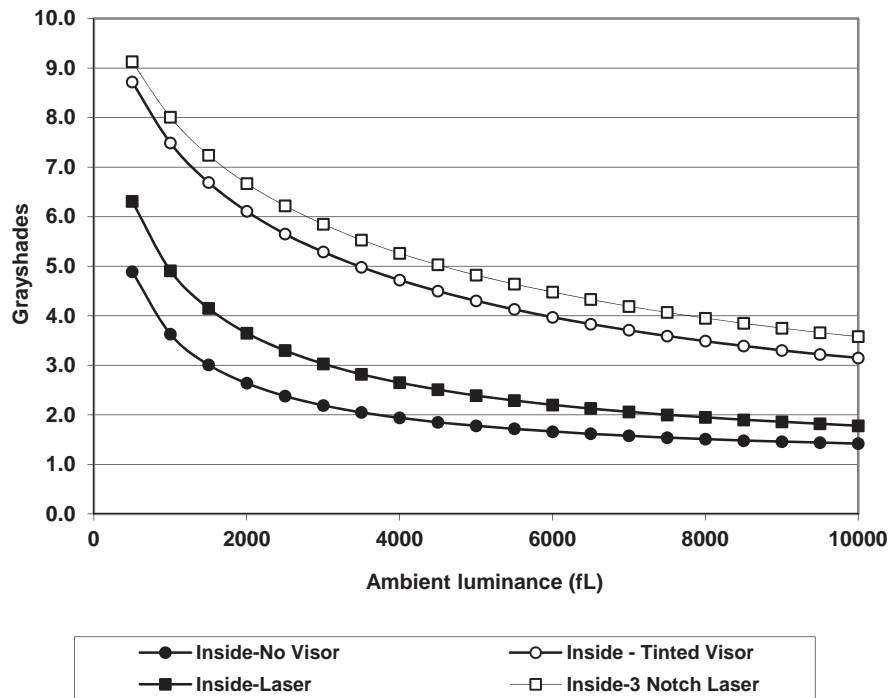


Figure A-2. Grayshades as a function of ambient luminance for the HMD mounted inside the visors.

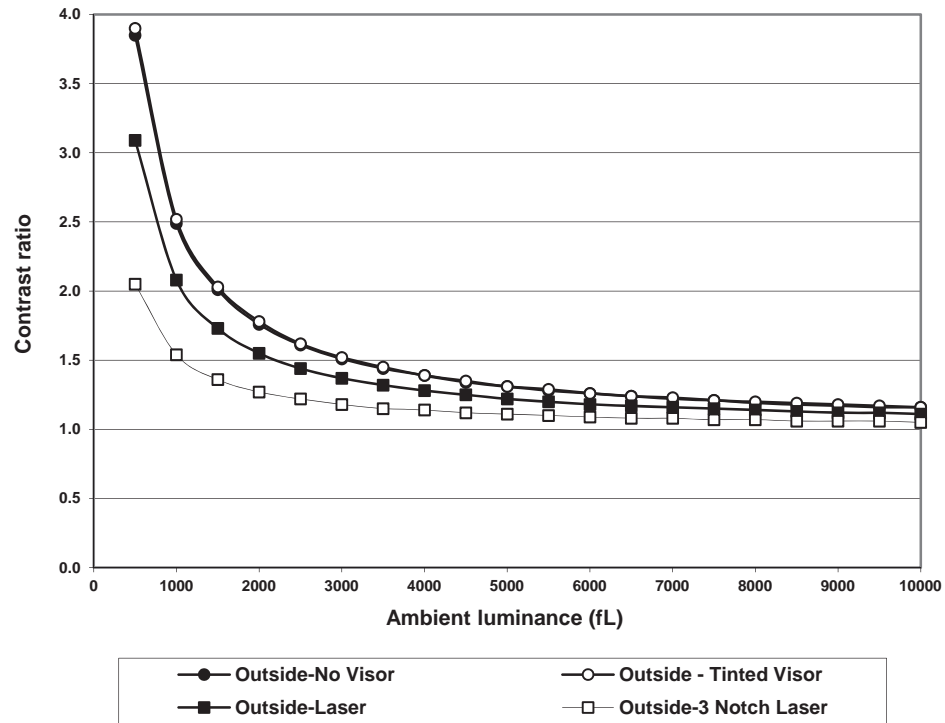


Figure A-3. Contrast ratios as a function of ambient luminance for the HMD mounted outside the visors.

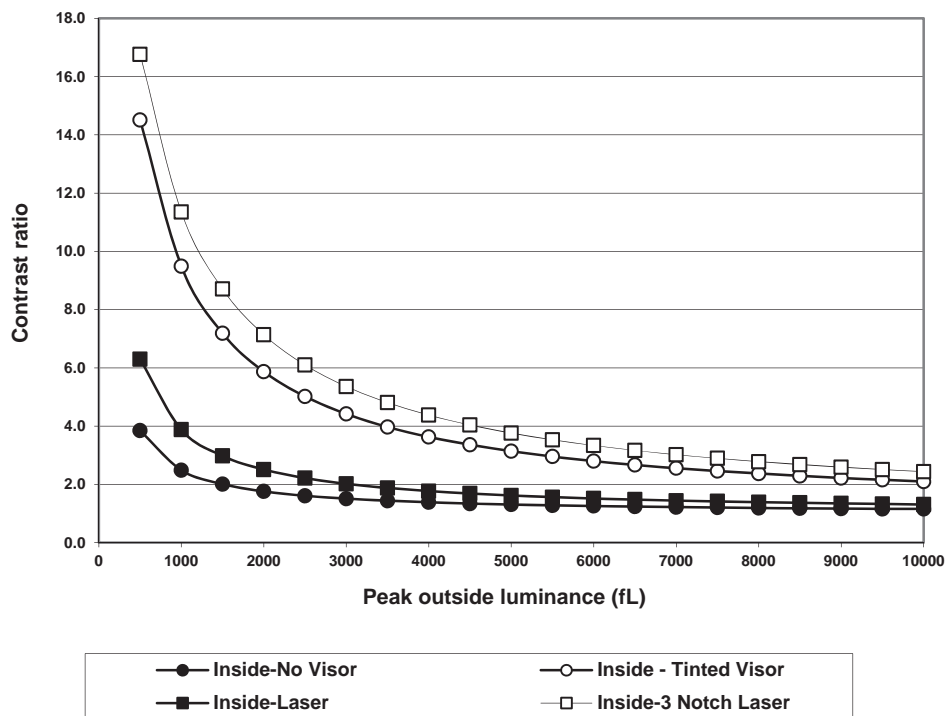


Figure A-4. Contrast ratios as a function of ambient luminance for the HMD mounted inside the visors.

Appendix B. Composite Images

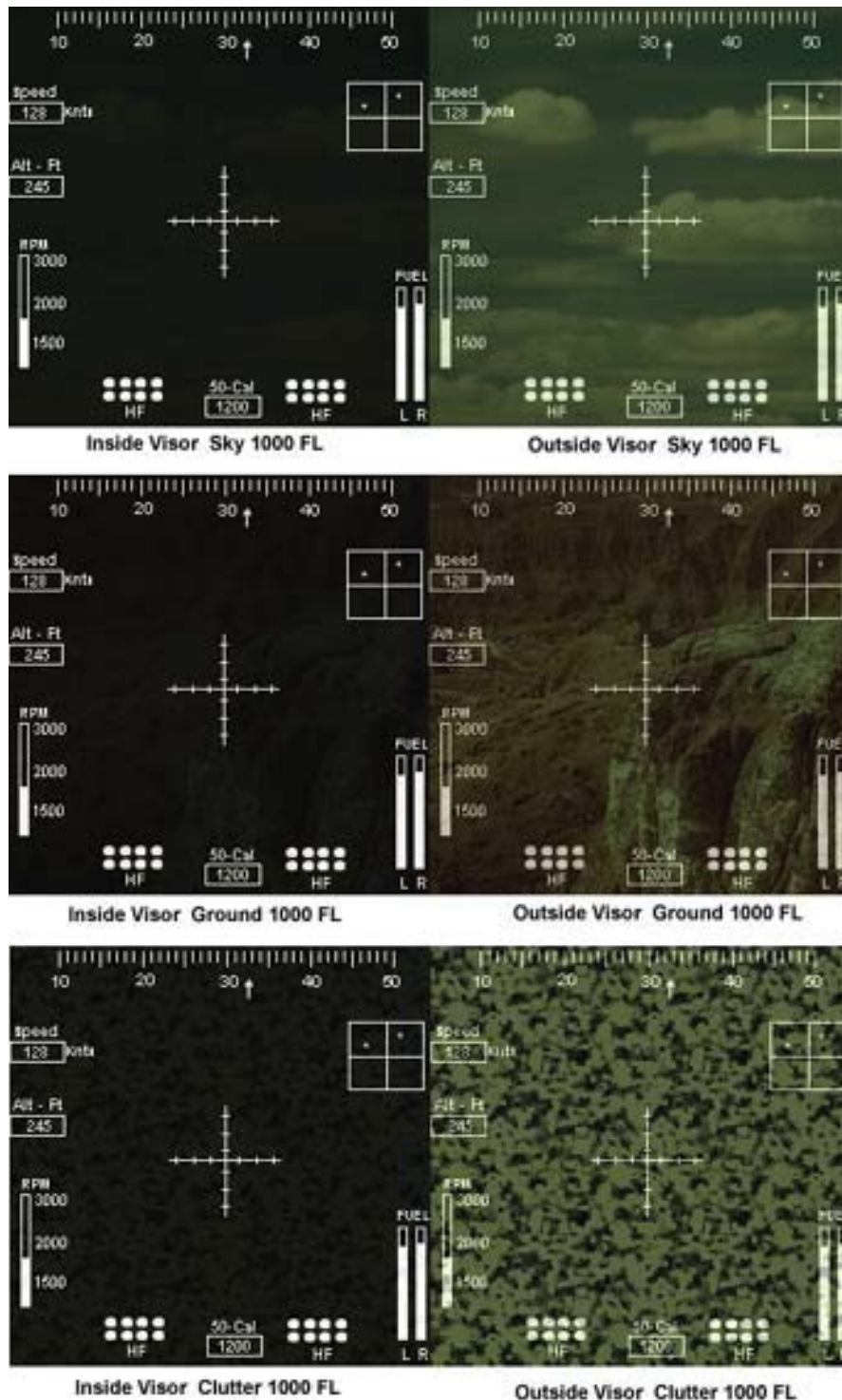


Figure B-1. Composite images of symbology plus background at a simulated peak luminance of 1000 fL. Images on the left are for the HMD mounted on the inside of the Gentex tinted visor and images on the right are for the HMD mounted outside the visor.

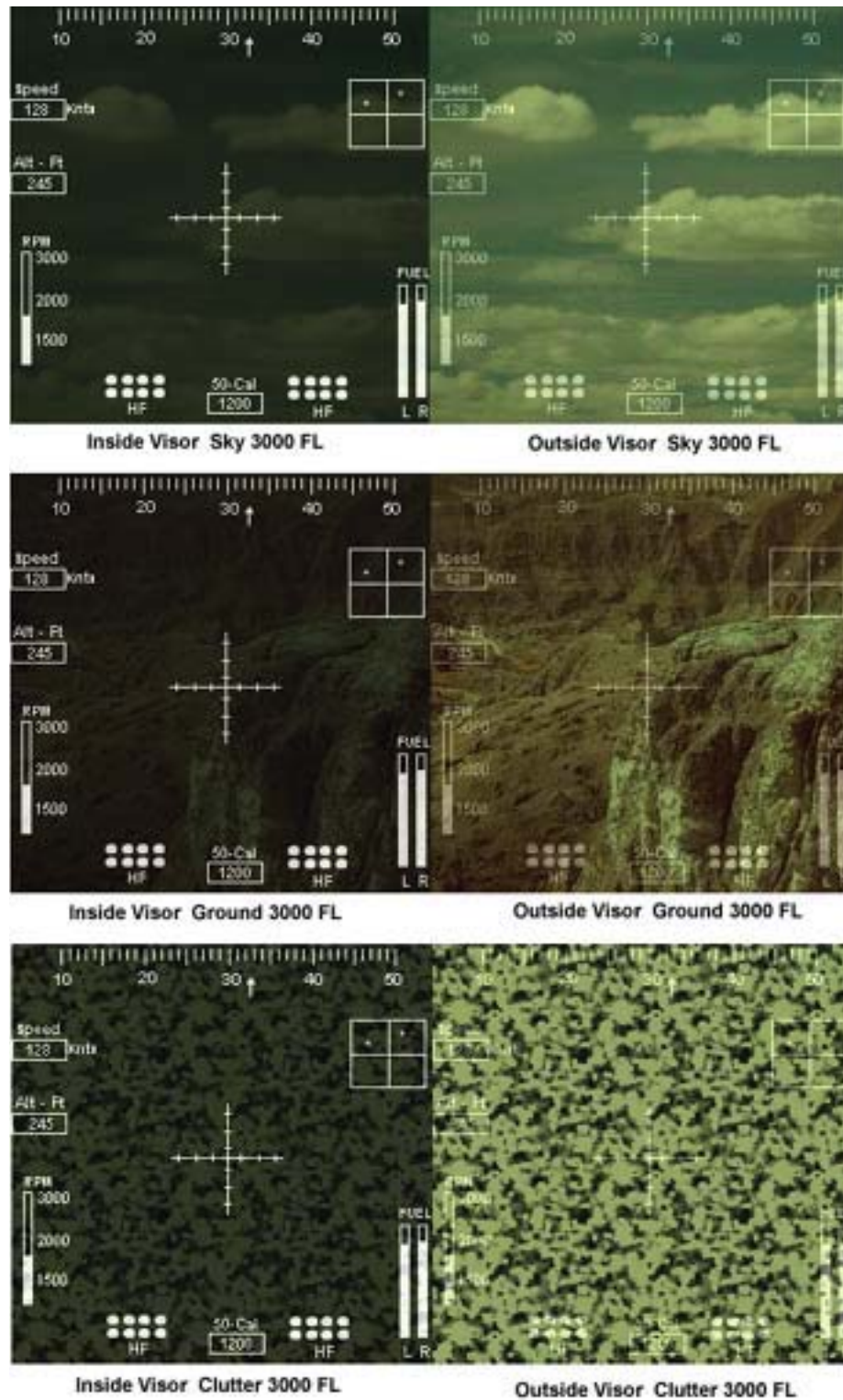


Figure B-2. Composite images of symbology plus background at a simulated peak luminance of 3000 fL. Images on the left are for the HMD mounted on the inside of the Gentex tinted visor and images on the right are for the HMD mounted outside the visor.

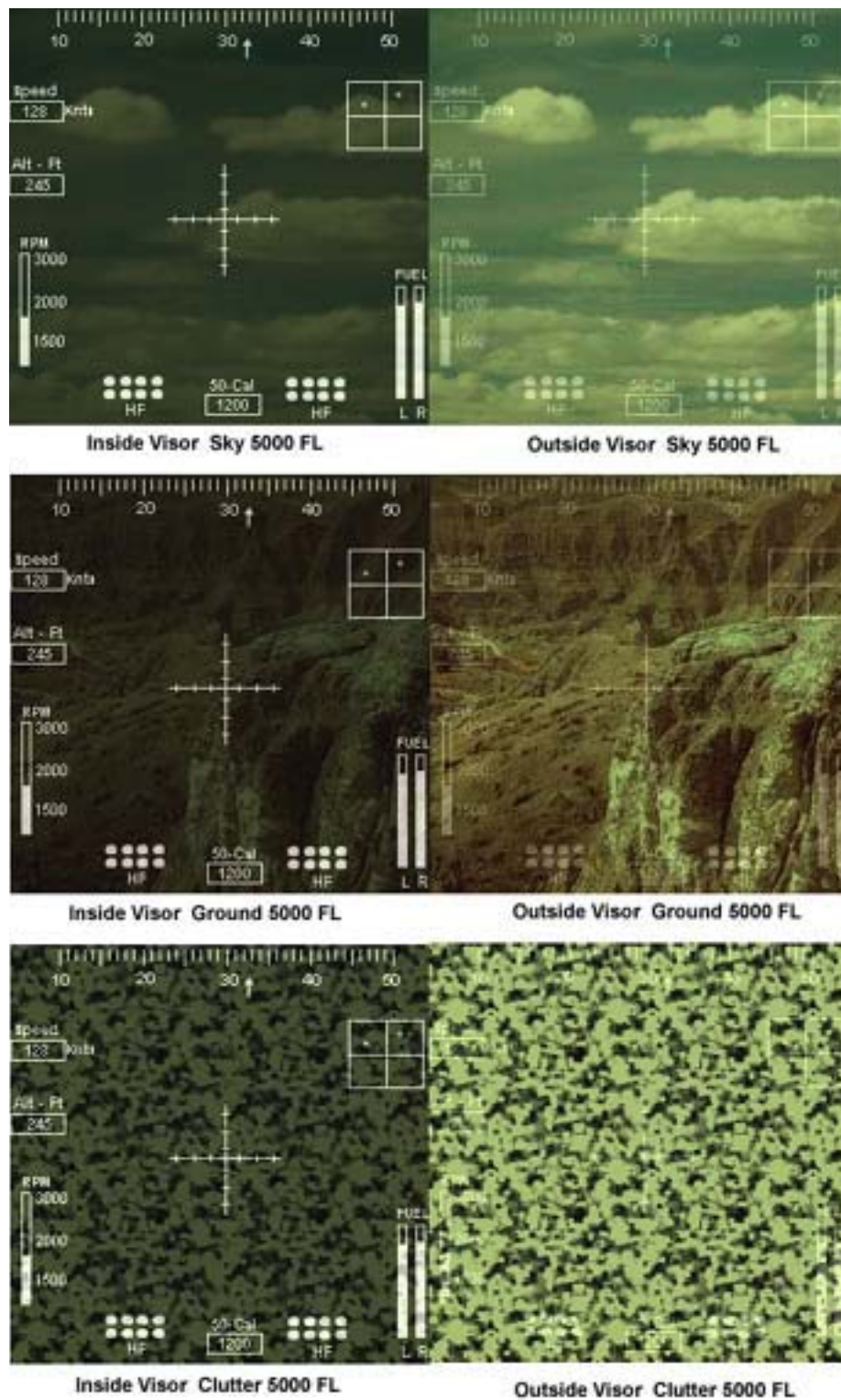


Figure B-3. Composite images of symbology plus background at a simulated peak luminance of 5000 fL. Images on the left are for the HMD mounted on the inside of the Gentex tinted visor and images on the right are for the HMD mounted outside the visor.

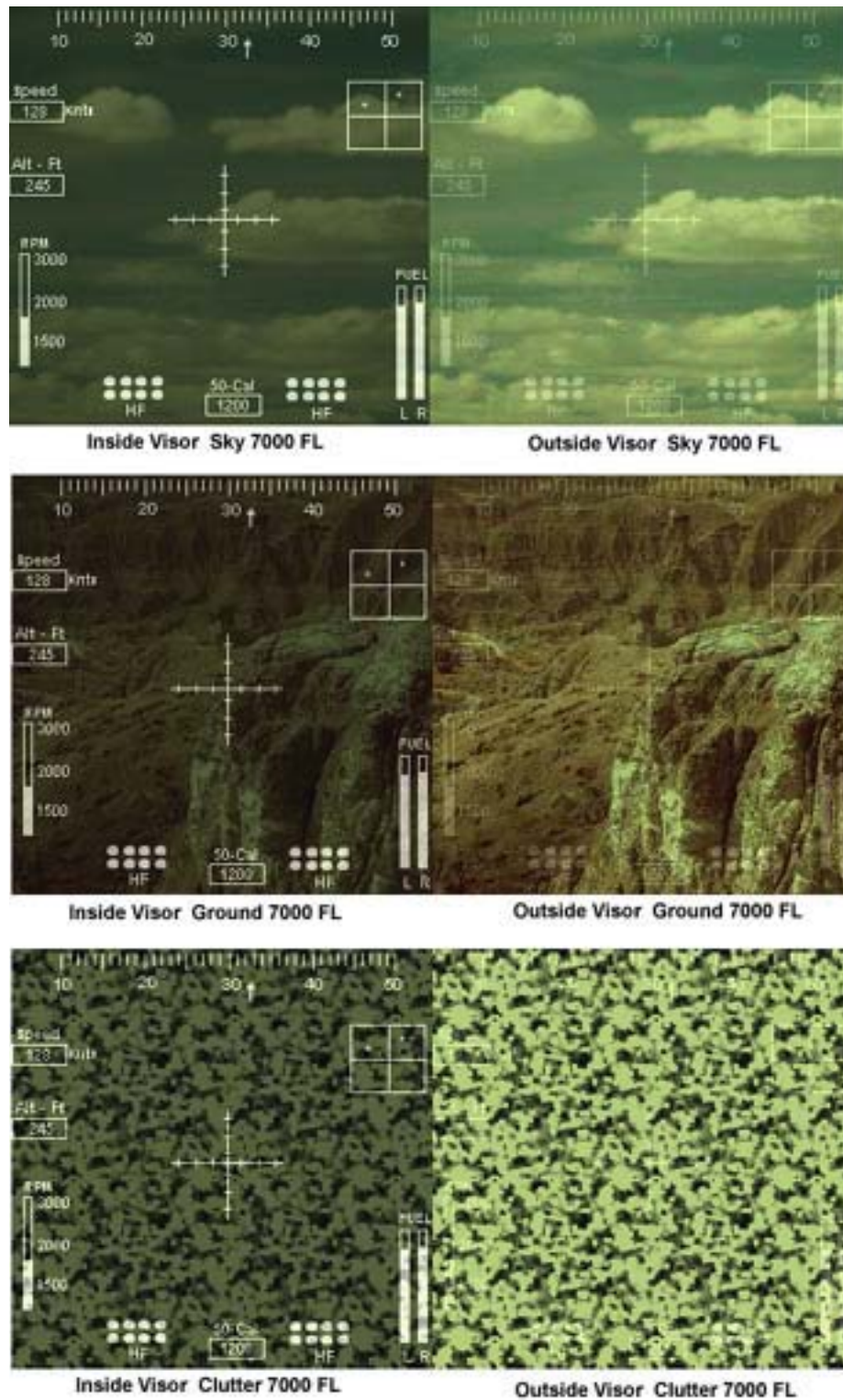


Figure B-4. Composite images of symbology plus background at a simulated peak luminance of 7000 fL. Images on the left are for the HMD mounted on the inside of the Gentex tinted visor and images on the right are for the HMD mounted outside the visor.

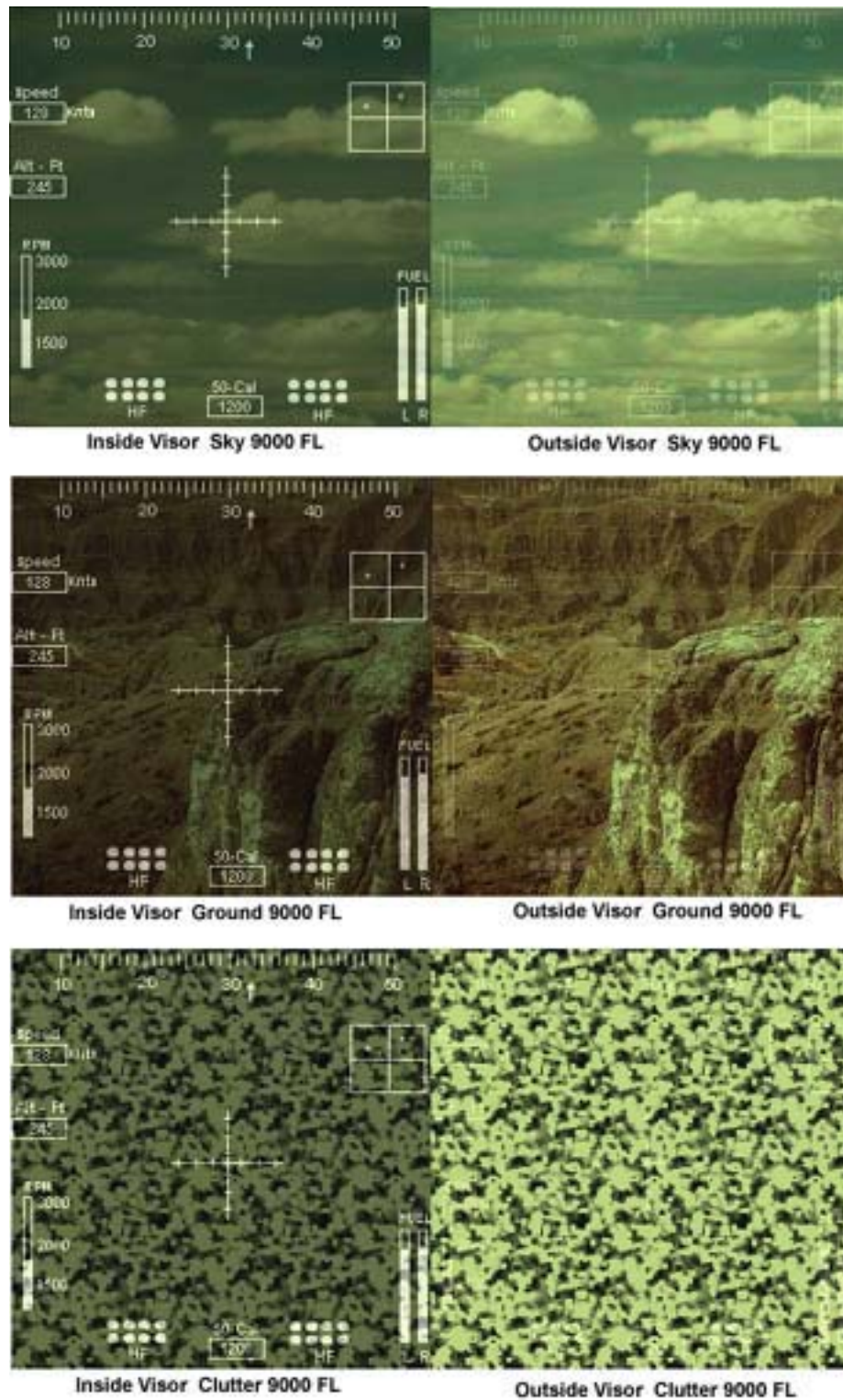


Figure B-5. Composite images of symbology plus background at a simulated peak luminance of 9000 fL. Images on the left are for the HMD mounted on the inside of the Gentex tinted visor and images on the right are for the HMD mounted outside the visor.

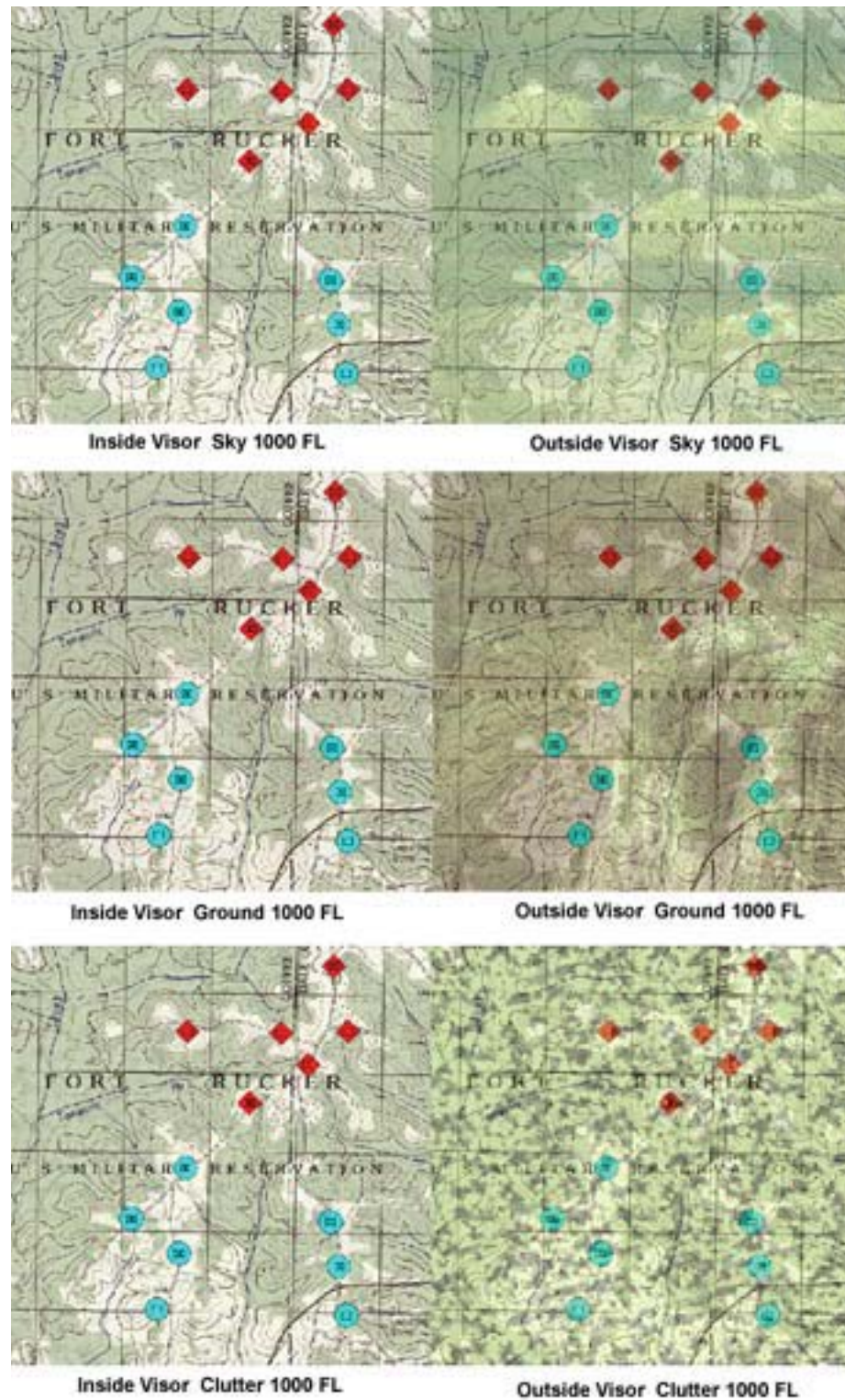


Figure B-6. Composite images of situational maps plus background at a simulated peak luminance of 1000 fL. Images on the left are for the HMD mounted on the inside of the Gentex tinted visor and images on the right are for the HMD mounted outside the visor.

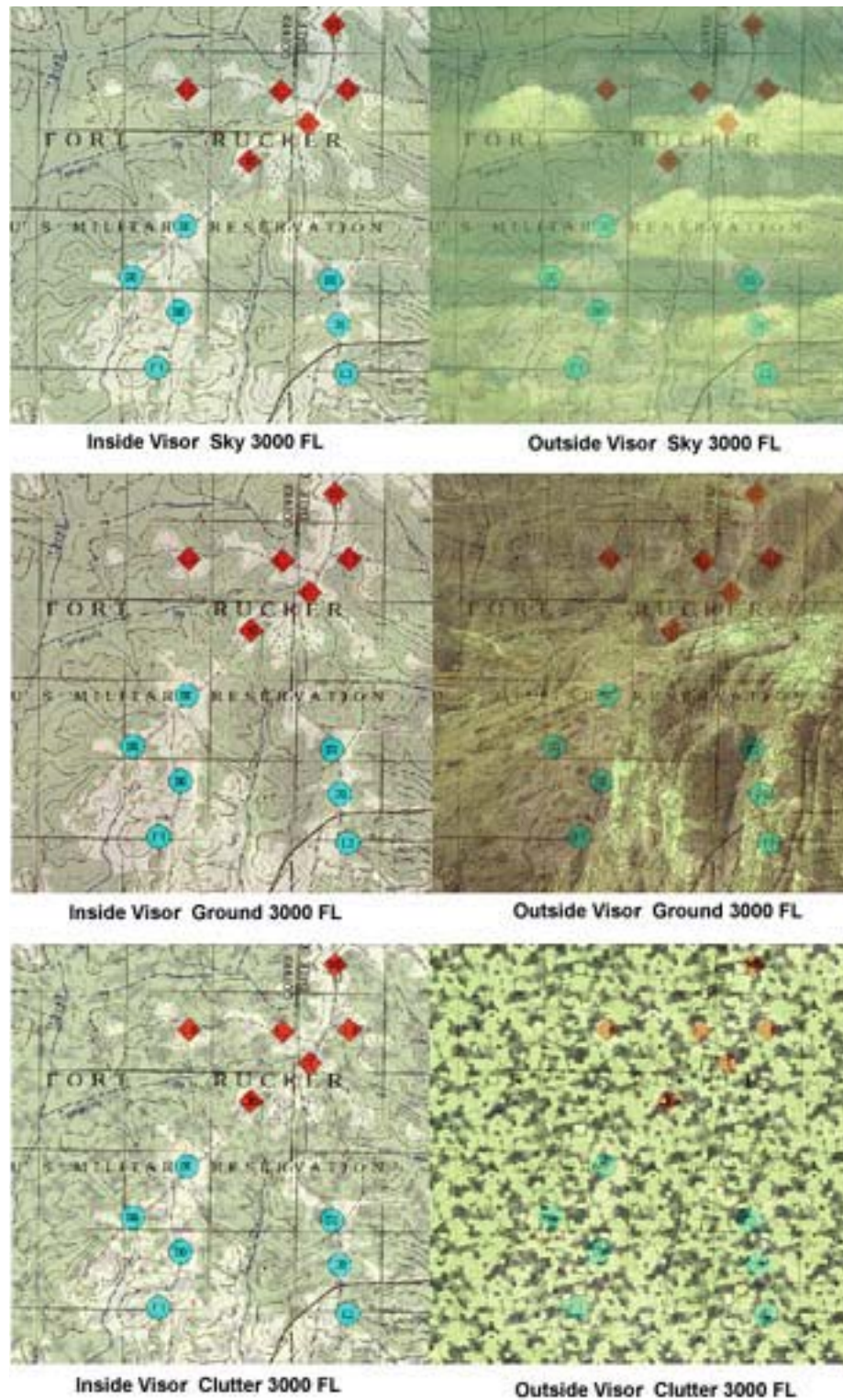


Figure B-7. Composite images of situational maps plus background at a simulated peak luminance of 3000 fL. Images on the left are for the HMD mounted on the inside of the Gentex tinted visor and images on the right are for the HMD mounted outside the visor.

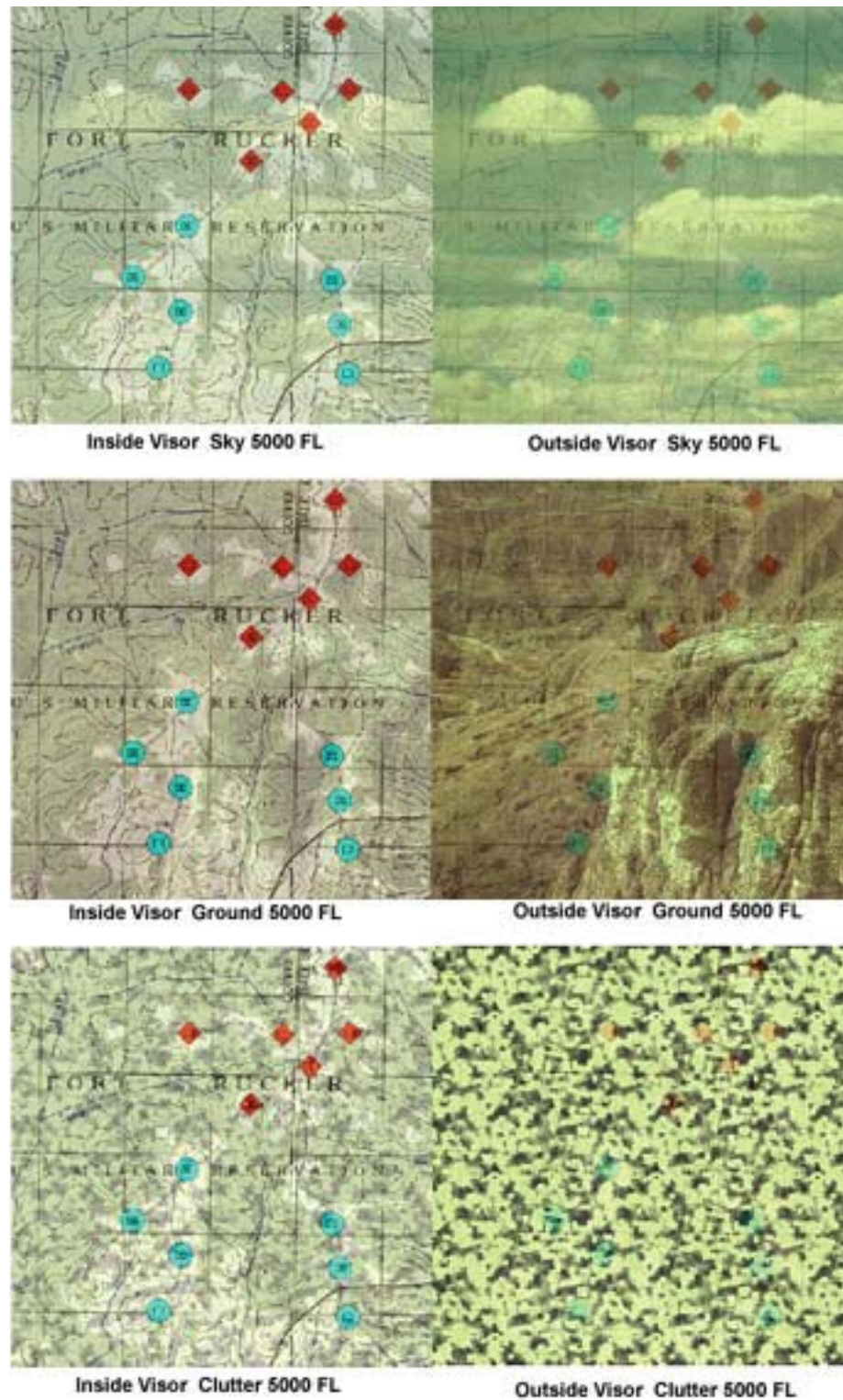


Figure B-8. Composite images of situational maps plus background at a simulated peak luminance of 5000 fL. Images on the left are for the HMD mounted on the inside of the Gentex tinted visor and images on the right are for the HMD mounted outside the visor.

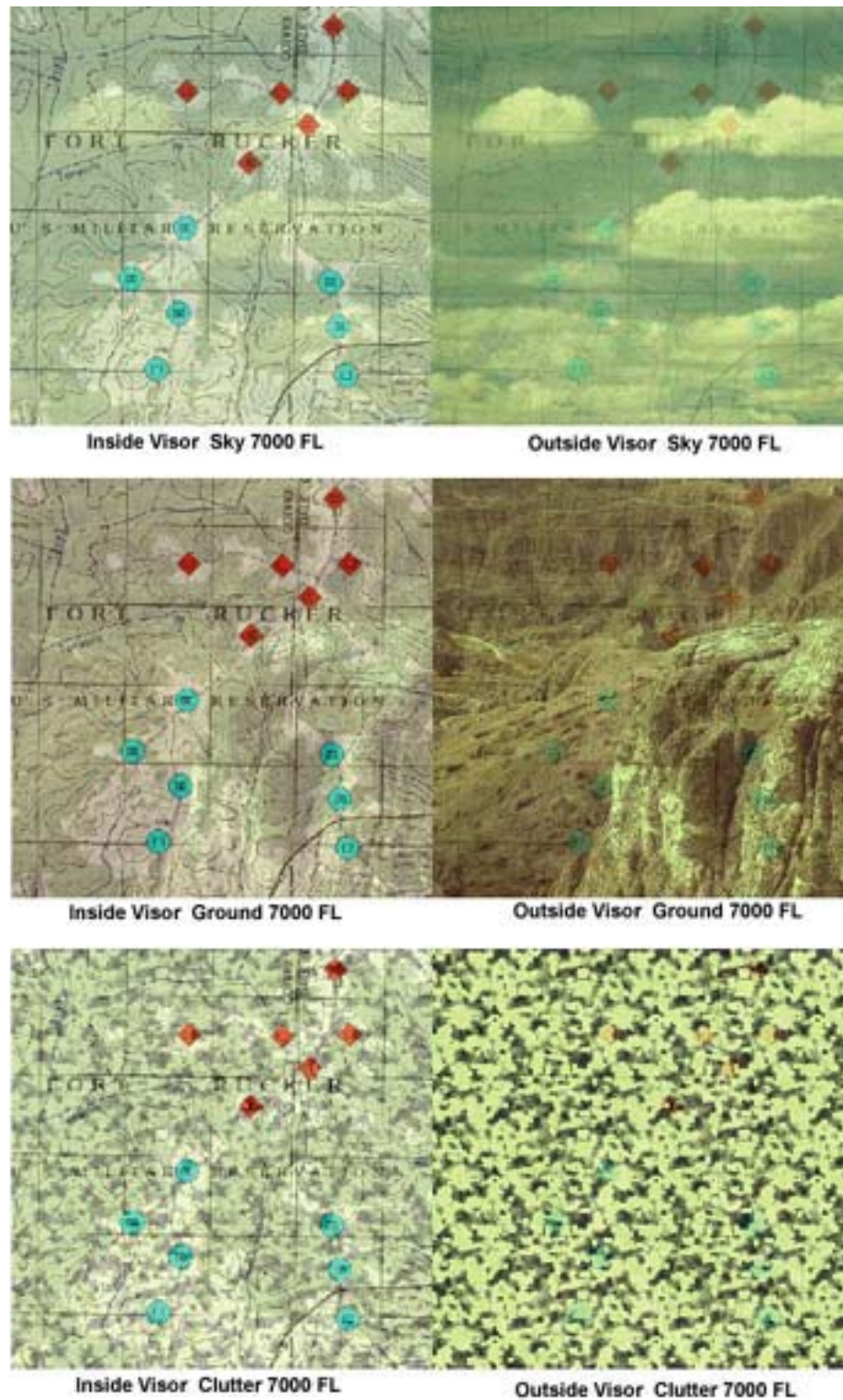


Figure B-9. Composite images of situational maps plus background at a simulated peak luminance of 7000 fL. Images on the left are for the HMD mounted on the inside of the Gentex tinted visor and images on the right are for the HMD mounted outside the visor.

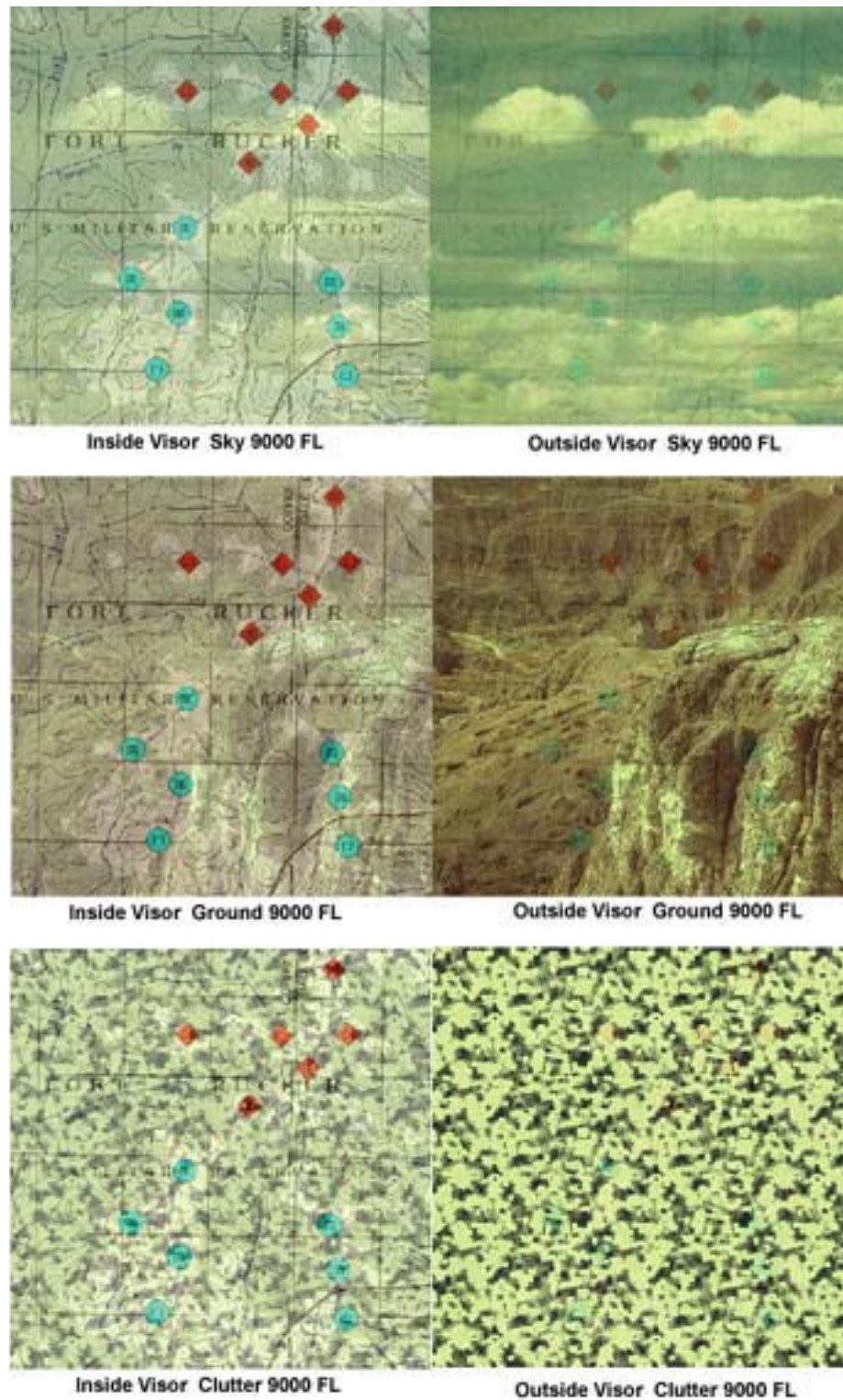


Figure B-10. Composite images of situational maps plus background at a simulated peak luminance of 9000 fL. Images on the left are for the HMD mounted on the inside of the Gentex tinted visor and images on the right are for the HMD mounted outside the visor.



Department of the Army
U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama, 36362-0577
www.usaarl.army.mil



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